« Réseau PRO »: analyzing the French context of field experiments assessing agronomic, environmental and sanitary impacts of organic residues recycled in agriculture

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Abstract
To assess agronomical values and putative impacts of the great variety of organic residues (OR) recycled in agriculture, many French organisms have carried out field experiments. One of the "Réseau PRO" network aims was to inventory those French field experiments to report the national experimental context and highlight possible needs of references. A total of 437 field experiments implemented between 1974 and 2013 have been inventoried. Trials were mainly monitoring grain crops (58% of all trials) and assessing urban/industrial OR and livestock manures (respectively in 60% and 40% of all trials). The main studied topics were nitrogen availability (short-, middle- and long-term effects) and P, K, Mg, S fertilization effects, followed respectively in 90% and 35% of the trials. Few trials were devoted to the study of contaminant fate. The survey also highlighted a need of references for digestates which have been studied in less than 2% of the total trials.

Introduction
The nature of organic residues (OR) recycled in agriculture and the actual effects after their application can vary greatly, due to the origin of raw materials (urban, agriculture, industry) and their treatments (composting, anaerobic digestion, etc.). In France, many field experiments have been carried out by different organisms (research or technical institutes, …) to assess in situ agronomical values and putative impacts of OR recycling in agriculture, for a large diversity of OR, in various contexts of soils and climates and for different agro-systems. The "Réseau PRO" network has been initiated in 2011 by a consortium of professionals involved in the French OR recycling to share (i) methods devoted to the study of OR recycling and (ii) data acquired in most of the field experiments carried out in France. Before centralizing those different data in the same databases, the first objective of the "Réseau PRO" network was to inventory all the existing field experiments, the associated setting-up and analytical characterization methods, their purpose and field of study.
The present paper therefore aimed at (i) synthetizing the results of this national inventory of field experiments conducted on the recycling of OR, and (ii) highlighting the main studied topics and contexts as well as possible lack of references for some OR, agro-pedo-climatic contexts or thematic.

Material and Methods
The survey consisted in an Excel file displaying different tabs designed to describe the experimental devices and the context of the in situ studies: context and general information (localisation, starting date, etc.), historical background and physico-chemical context (previous crop rotation, soil characteristics, etc.), OR tested (nature, raw materials, treatments), field experimental design, followed compartments of the agro-system (i.e. soil, plants, OR, water, gas emissions), measurements/analyses, analytical methods, data registered and databases associated. The data acquired on those trials will be later centralized and stored in the "Réseau PRO" databases. The targeted field experiments were conducted with various experimental designs and durations and with various type of OR tested, with or without treatment repetitions, in organic or conventional agriculture. The survey was addressed to all French organisms involved in the study of OR recycling in agriculture, such as technical and research institutes, chambers of agriculture or actors of the OR valorisation industry. Descriptive statistics were performed on the inventory results.

Results
General data

A total of 437 trials were inventoried. The inventoried field experiments have been initiated between 1974 and 2012 and only 35 of them are still running in 2012. The average duration of a trial is about 2 years. Among field experiments in place each year since 1974, the field experiments conducted for more than 2 years represented the majority of the studies (figure 1).

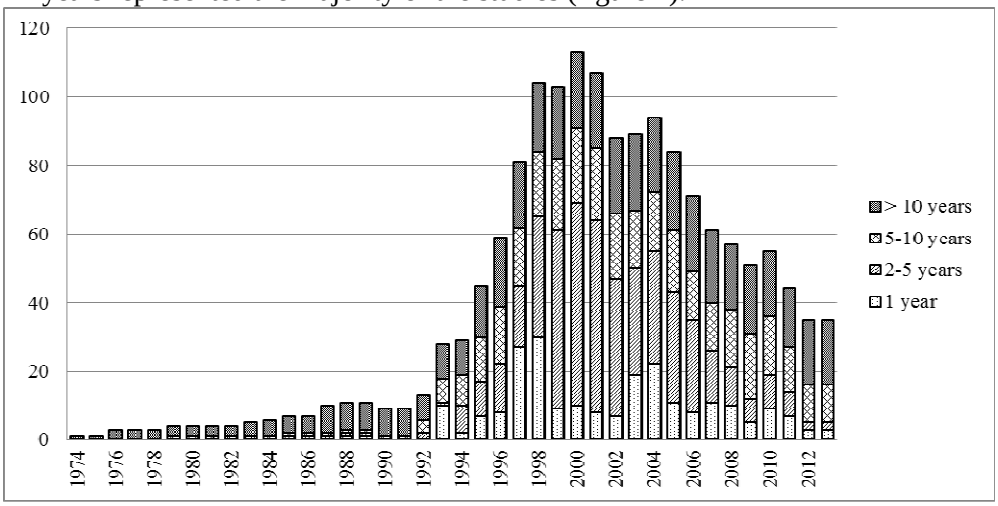

Figure 1. Evolution of field trial number and their duration between 1974 and 2012

As shown in figure 1, the number of field plots increased remarkably from 1992 to 2000 and then decreased until nowadays. Before 1992, only long-term field trials have been registered, probably partly because the memory and results of short-term trials have been lost. After 1992, most of the trials were short term (1 year) to middle term plots (2-10 years). Some long-term trials (19 trials) have been initiated at the beginning of the years 2000's and are still ongoing.

Most of the trials were monitored with grain crops (58%), mainly wheat, maize and colza while fruit growing, agroforestry, wine growing, grassland and market gardening were less studied (studied on less than 7% of total trials). The study showed that the origin of the tested OR depended on the type of crops: for example, nearly 98% of the trials monitoring grasslands assessed farm manures application and 100% of the trials in forestry focused on the urban and industrial wastes.

Studied Organic Residues

Among all the inventoried trials, the employed terminologies to name or describe OR were very diverse, even for the same type of OR. This diversity was an obstacle to identify and compare OR studied in the inventoried trials. Therefore, the referencing method presented in the poster of Bell et al [3] was used to process the survey results. This method has been established to describe and classify OR applied in the French territory into classes depending on the origin of the raw materials and the applied treatments. The results presented in this study take into account the referencing method which allow classifying OR into 4 classes depending on the origin of raw materials: urban/industrial OR, livestock manures, other animal/vegetal OR, and mixed OR (OR with components coming from one of the three origins above). Within those origin classes, OR are divided in "great types" defined by the treatment or absence of treatment applied to the raw materials composing the final OR.

The results of the survey showed that 2 different OR were usually studied in each field experiments. Those OR could have either the same origin or not. According to the survey, about 60% of inventoried trials were assessing urban/industrial OR, about 40% livestock manures, 18% other animal/vegetal OR and 18% mixed OR. Table 1 shows the repartition of "Great type of OR" among the 4 origin classes.

The majority of the studied OR in the 437 inventoried field experiments was non-composted or non-digested farm manures and urban or industrial sludge, representing respectively 36% and 28% of the total trials (table 1). Digestates were, on the other hand, studied in less than 2% of the total trials. As expected, a large variety of raw materials composed the studied OR: about 80 different types of raw materials were listed. Most of those raw materials were farm manures or had urban or industrial origin: sewage sludge (18% of total organic raw materials), cattle manure (9%), feathers flour (7%), green waste (7%) and poultry manure (7%). The sizeable number of experiments conducted in organic systems (27% of all trials) can explain this large variety of registered raw materials.

Table 1. Percentage of inventoried trials assessing great types of OR

Origin of assessed OR	Great type of assessed OR	Percentage of trials
Urban or industrial	Urban or industrial sludge	28 %
	Agroindustrial by-products	19 %
	Composted urban or industrial OR	17 %
	Digested urban or industrial OR	0.2 %
Farm manures	Non-composted or non-digested farm manures	36 %
	Composted farm manure	14 %
	Digested farm manure	0.2 %
Other vegetal and/or animal OR	Animal organic matter (bone flour, etc.)	13 %
	Vegetal organic matter	5 %
	Composted animal or vegetal OR	2 %
Mixed	Mixed OR	11.9 %
	Composted mixed organic matters	6 %
	Digested mixed organic matters	0.9%

Studied topics and factors

The survey distinguished 11 different possible topics studied in the field experiments. Those field experiments could have been carried out to study one or several of those defined topics: 5 topics devoted to the agronomical effects of OR recycling (nitrogen, P-K-Mg-S, soil OM, soil pH and soil physical effects), 3 topics focusing on the environmental and sanitary putative impacts (Trace element (TE), organic trace contaminant (OTC) and pathogens fates) and 3 topics concerning more economical and societal aspects (i.e. crop quality, ecosystem services and economic impacts). The distribution of the inventoried trials between those 11 studied topics is presented in table 2.

Table 2: Studied topics and percentage of the inventoried trials for each studied topics

Studied topics	Percentage or trials studying the topic
Nitrogen effects	90%
short term N effects (≤ one year)	*54%*
middle term N effects (1 to 3 years)	*14%*
long term N effects (≥ 3 years)	*17%*
P-K-Mg-S fertilization effects	35%
Effects on soil OM	19 %
Physical effects on soil	10 %
Effects on soil pH	13%
Trace elements	21%
Organic trace compounds	6 %
Pathogens	2 %
Crops quality	27 %
Ecosystems services	5%
Economic impacts	9%

A majority of the trials assessed the nitrogen fertilization effects of OR applications (90%), especially the short term ones, with 54% of the total field experiments. The topic concerning the agronomical value of OR in terms of P, K, Mg and S inputs were studied in 35% of the trials. This figure includes trials focused on only one of these nutrients, two of them or all of them. The grouping of P, K, Mg and S in the same topic did not permit to distinguish the actual study of each nutrient taken separately. It is thus not possible to highlight a putative lack of reference for one of those nutrients. The effects of OR application on soil OM, pH and physical characteristics were usually studied on the same trials but less often than the other agronomic topics above (respectively in 19%, 13 and 10 % of the trials). The least studied topics corresponded to the evaluation of putative sanitary and environmental impacts as well as economical and societal aspects. Indeed, the study of OTC and TE fate, pathogens putative effects and ecosystems services represented less than 10% of the studied trials. The studied contaminants corresponded to those mentioned in the French regulations (NFU 44-095, NFU 44-051).

When considering the studied topics for each great types of OR, it was interesting to notice that some topics were preferentially studied for some types and great types of OR. For instance, whatever the origin of the OR is, composts were mainly studied in experiments devoted to assess P-K-Mg-S

fertilization effects, soil organic amendment effects and physical effects on soil: respectively 49%, 38% and 28% of the trials. This could be related to the expected effects of composted organic matters particularly in terms of organic matter amendment effect. On another hand, main themes studied on trials including industrial/urban OR, excepting nitrogen effects, were P-K-Mg-S inputs and TE fate (respectively 34% and 31% of trials), certainly due to the OR origin itself.
The inventory also highlighted some evolutions in trial objectives since 1974. Indeed, between 1974 and 2013, the number of field plots assessing nitrogen effects fluctuated between 80% and 100% of the total trials whereas other subjects of study rarely exceeded 50% of the total trials throughout this period. From the 90's, the inventory showed that subjects concerning economical and societal aspects (i.e. crops quality, economic impacts) and soil pH amendment effect were more and more studied but never exceeded 30% of total trials. During the 90's, it also seemed that OR of animal and/or vegetal origins (such as feathers flour, seaweed, etc.) were new studied OR, especially in organic agriculture cases. It could be related to the institutional recognition of organic agriculture in the 90's in France, and therefore to an increasing need of references on OR used in organic systems.
In regard of the studied themes, the studied factors that were mainly followed were OR nature (studied factor on 73% of trials) and OR applied dose (35%). Different levels of OR nature and OR dose applied were compared, mainly for the nitrogen and P-K-Mg-S inputs (respectively 91 and 40% of trials with OR nature as a studied factor and 93 and 32% of trials with OR applied dose). Other studied factor, such as the "partition of organic supply" was studied in less than 6% of the trials. Nevertheless, it is interesting to notice this factor so called "partition of organic supply" by experimenters is actually a combination of 4 factors: number of OR application, OR nature, period of OR application and OR applied dose. It was particularly studied in organic agriculture as 91% of organic plots studied it. More than studying the 4 factors as distinct items, the aim was to compare different fertilizing strategies, with the purpose of staying close to the nitrogen needs of crops. It is then logical to state that the different levels of "partition of organic supply" were compared for their nitrogen effects (100% of trials with this studied factor) and crop quality impacts (78%), i.e. crop protein or nitrate contents.

Conclusion and perspectives

The survey demonstrated a great unbalance within the studied effects of OR application in agriculture. Indeed, nitrogen effects was the main studied topic, whatever the agricultural system (organic or conventional), type of crops or OR great type are. Few trials were assessing the contaminants fate (OTC, pathogens and TE specified in the French regulations), probably due to the cost of the analyses and/or the monitoring requirements. Moreover, the survey revealed a need of references for digestates, whatever the source of organic matter is, so as ADEME (French agency for environment and energy management) underlined [2]: whereas production of digestates increased those last few years, due to its economic benefits, references on impacts of digestate applications on soils are not sufficient yet.
As a result, in addition to the use of data centralized and shared between "Réseau PRO" partners for statistical analyses and modelling, one of the objectives of the "Réseau PRO" network is to point out needs of references as for contaminant putative input and fate after OR application, new OR which could be used by farmers and to encourage future experimentation to study new topics, such as emerging contaminants and phosphorus supply shared by OR applications.
The purpose of "Réseau PRO" network is therefore to create the necessary synergy and resources to allow such studies. A guide book will be published in the beginning of 2014. It will aim at any field experimenter and will include protocol for each topic (table 2) and procedures for the management of field experiments assessing OR agriculture applications. This guide purpose is to implement a coherent national field experiment network that will permit to collect and share homogenised data acquired in different agro-pedo-climatic contexts and for various OR.

References

[1] Ducasse-Cournac AM, Leclerc B, Muller F, 2002. Inventaire national des essais agronomiques réalisés avec des matières organiques et minérales d'origines urbaine et industrielle. 192p.
[2] ADEME, 2011. Qualité agronomique et sanitaire des digestats. 250p.
[3] Bell A, Michaud A, Schaub A, Trochard R, Sagot S, Dumont S, Parnaudeau V, Leclerc B, De Chezelles E, Houot S, 2013 : « Réseau PRO »: Establishing a method for the referencing of organic residues recycled in agriculture in a database. Ramiran 2013.